Forum for experts

Vascular trauma: selected historical reflections from the western world

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【**Abstract**】In the spirit of international exchanges of knowledge with colleagues from all over the world, who are interested in the care and treatment of vascular trauma, we offer selected historical reflections from the western world on vascular trauma. Whereas there are a number of key individuals and a variety of events that are important to us in our writing, we know essentially nothing about what is written by other cultures and, particularly, the Chinese. It is well recognized around the world that Chinese surgeons are among the first to be highly successful in re-plantation of severed extremities, repairing both injured arteries and veins. Also, we recognize that there are contributions in other parts of the world, which are not well known to us collectively. Contributions from the Arabic speaking part of the world come to mind because there is periodic brief reference. We offer our perspective hoping that there will be one or more Chinese surgeons who will offer us the benefit of sharing their perspective on important historical contributions to the managing of vascular trauma outside of the western world, and, particularly, the English speaking literature. Once again, we encourage our colleagues in the Arabic speaking world to provide us with their perspective of the development and management of vascular trauma.

Key words: ***Vascular system injuries; History; Western world; International educational exchange***

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Reflecting on the historical contributions to the management of injured arteries and veins, vascular trauma, in the western world, particularly in the English speaking world, focuses on the identified contributions in the western world. The purpose of this manuscript is to reach out to colleagues from all over the world, who are interested in the care and treatment of vascular trauma, and to describe briefly the contributions, which we believe to be important to this discipline and have been made by surgeons in the western world. One of the authors (Rich NM) was a recent participant of Endovascology 2010 in Shanghai, People's Republic of China, and reviewed the history of vascular trauma at this important conference. We in the western world would be most appreciative if Chinese colleagues would provide us with a review of the developments in the management of vascular injuries from their perspective based on accomplishments and contributions made in Chinese medicine and surgery. As the world continues to "shrink," we can all continue to enjoy the privilege of learning from each other. It is well recognized around the world that Chinese surgeons are among the first to be highly successful in re-plantation of severed extremities, repairing both injured arteries and veins. Also, we recognize that there are contributions in other parts of the world, which are not well known to us collectively. Contributions from the Arabic speaking part of the world come to mind because there is periodic brief reference. Once again, we encourage our colleagues in the Arabic speaking world to provide us with their perspective of the development and manage-

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ment of vascular trauma.

Vascular Trauma, written by Rich and Spencer and published in 1978 by WB Saunders Company, USA, provides a broad historical review of the management of vascular trauma.[1] There is an extensive associated source of references. The majority of the material is based on battlefield experiences, particularly from the 20th century by American surgeons with specific emphasis on the Vietnam War (1965-1972). A representative "classic" case from battlefield experience is depicted in Figure 1 from the early experience in the Vietnam War by the first author at the Second Mobile Army Surgical Hospital in the Central Highlands of the Republic of Vietnam in 1966. *Vascular Trauma*, *2nd edition*, by Rich, Mattox and Hirshberg and published by Elsevier/WB Saunders Company, USA in 2004, has multiple contributing authors and focuses more on the civilian management of vascular trauma.[2] However, the broad historical material and reference source (nearly 3 000 references) related to the management of vascular trauma are included. Selected references are identified alphabetically, which will be of value to anyone with an interest in the history related to the management of injured arteries and veins. Currently, the third edition of *Vascular Trauma* is under early development and will be reviewed in further detail at the end of the manuscript.

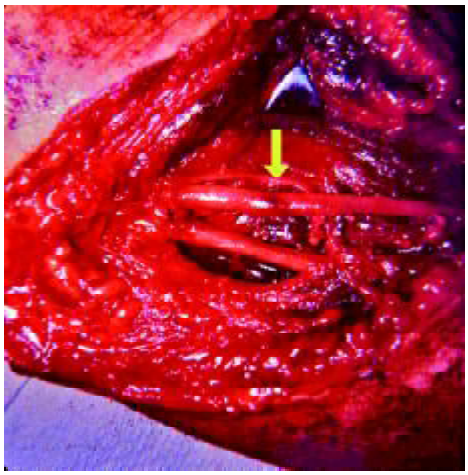

Figure 1. Contustion of the brachial artery caused by high velocity cavitation effect, with the bullet not actually striking the artery. In addition to the adventitial hemorrhage, the intima was disrupted and thrombosis of the brachial artery occurred approximately three hours after wounding. The brachial artery was distended with blood to the left, cephalad, and constricted right, toward the hand, where blood flow was prevented by the thrombus at the site of injury. (Norman M. Rich, Second Surgical Hospital, An Khe, Republic of Vietnam, 1966.) (From Rich NM, Spencer FC: Vascular Trauma. Philadelphia: WB Saunders, 1978.)

The *Journal of Vascular Surgery*, which is considered the premier vascular journal in the western world by most, has a new section as of this year of 2010 called, "*Historical Vascular Vignettes*". The primary author has a contribution, "Halsted-Holman vascular trauma legacy," which outlines briefly the first author's personal experience with the vascular trauma legacy in the 20th century in the western world.[3] The second contribution, "the influence of Dominique Jean Larrey on the art and science of amputations," by two of the authors (Rich NM and Welling DR) has additional historical perspective to the management of vascular injuries, particularly on the battlefield over the past two centuries in the western world.[4] The most recent *Historical Vascular Vignette*, published in November 2010, emphasizes the role of temporary intraluminal vascular shunts in both arteries and veins, used by American surgeons in both Iraq and Afghanistan in the early part of the 21st century. Two of the authors (Rasmussen TE and Rich NM) contributed to the documentation of this emerging and expanding technology in the management of vascular trauma.[5]

In the following brief remarks, selected reference material[6-19] will be included for emphasis, noting as above that all of these references are included in *Vascular Trauma*.[1,2] Table 1 notes selected contributions to the management of injured arteries and veins over the centuries from a western world perspective.

Early contributions from Egypt, Greece and Rome

Circa 1600 BC Egyptians (as described by the Ebers' papyrus, discovered by Ebers at Luxor in 1873) noted one of the earliest records of various methods to obtain hemostasis.[18] Mineral or vegetable matter used as styptics, which included antimony, copper sulfate and lead sulfate, were popular. Hemostasis utilizing these forms was described subsequently all over the world.

For more than 2 000 years, management of vascular injuries on the battlefield concentrated on control of hemorrhage by pressure dressings and bandaging. This had been depicted in the ancient Greek medicine with the bandaging of Patroclus' extremity wound by Achilles (circa 500 BC). From the excavation in Pompeii, which was covered by ash in 79 AD from the erupting Mount Vesuvius volcano, we know that instruments were used in wound management by the Romans. Also, in the Roman Empire (2nd century), we learned about

collateral circulation from Antyllus. At the same time, vessel ends were ligated by Galen, a Greek physician living in the Roman Empire. Galen stressed the differences in identifying the source of bleeding. He advised placing a finger on the orifice of a bleeding superficial vessel for a period of time to initiate the formation of a thrombus, leading to cessation of bleeding. However, he noted that if the vessel was deeper, it was important to determine whether the bleeding was coming from an artery or a vein. With a vein injury, pressure or a styptic usually sufficed. With an arterial injury, however, ligation with linen was recommended. Further details were outlined in "an historic tour of vascular injury management: from its inception to the new millenium."[15]

The Dark Ages in Europe (400 AD-1000 AD)

For hundreds of years, the advancement in medicine and surgery from ancient Greece and Rome were lost during the Dark Ages in Europe.

The renaissance in Europe (1100 AD-1600 AD)

Ambroise Paré, the great French military surgeon of the 16th century, who made many contributions to the management of battlefield casualties, particularly to the management of vascular injuries. Paré recalled the ligature of vessels in Rome in the 2nd century when he ran out of boiling oil used to cauterize battlefield injuries to control hemorrhage. He made an important additional contribution in devising an instrument, the *bec de corbin*, which could grasp the end of injured vessels, allowing easier ligature of bleeding vessels and control of hemorrhage (Figure 2).

Table 1. Selected contributions supporting the management of vascular injuries

Surgeon	Year	Contribution
Galen	2nd century	First described ligature of vessels
Antuyllus	2nd century	First described collateral circulation
Paré	16th century	Re-established ligature of vessels/Used instruments
Hallowell-Lambert	1759	First arterial repair with pin and thread
Broca	1762	Suture of a longitudinal incision in artery
Glück	1881	Small ivory clamps in vessel repair
Schede	1882	First lateral suture repair of femoral vein
Jassinowski	1889	Fine needles and silk in vascular surgery
Burci	1890	Continuous suture for vascular repair
Heidenhain	1894	Catgut suture of a 1-cm iatrogenic laceration
Murphy	1896	First end-to-end anastomosis of an artery
Dörfler	1899	Fine needles and sutures through all vascular layers
Clermont	1901	End-to-end anastomosis of inferior vena cava
Carrel, Guthrie	1902	Triangulation method of arterial anastomosis
Goyanes	1906	Vein graft repair, popliteal vein used for popliteal artery
Lexer	1907	Saphenous vein graft in an artery
Makins	1914-1918	First chronology of arterial injuries: 1 202 British casualties in World War I
Holman	1937	Arteriovenous fistula pathophysiology
DeBakey, Simeone	1942-1945	Arterial injury study: 2 471 American casualties in World War II in Europe
Hughes, Spencer	1950-1953	Established combat vascular repair in American casualties during the Korean Conflict
Rich	1965-1972	Established Vietnam Vascular Registry
Rich, Hughes	1968-1970	Emphasized lower extremity venous repair in American casualties during the Vietnam War
Barros D'Sa	1979-1999	Advocated use of temporary vascular shunts
Rasmussen, et al	2003-2009	Popularized temporary vascular shunts in the Iraq War
Clouse, et al	2005-2008	Established Combat Vascular Registry in Balad, Iraq

Note: adapted in part from Rich NM: Vascular Trauma. Surg Clin North Am 1973;53:1367-1392.

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Vesalius in Padua in the 16th century emphasized the importance of anatomy, which, obviously, was very important to surgeons with an interest in arteries and veins. In the 17th century in England, William Harvey described circulation. This provided emphasis on the importance of both arteries and veins.

18th century in Europe

The anatomist William Hunter in England, the elder brother of John Hunter by ten years, emphasized the pathophysiology associated with arteriovenous fistulas. In 1759 he described cardiac enlargement and enlargement of the artery proximal to an arteriovenous fistula. John Hunter expanded much of his brother's work, adding many other valuable contributions ranging from the management of gunshot wounds to the broad collection of pathologic specimens that continue to be maintained in the Royal College of Surgeons of England in London (recognizing that many of the specimens were destroyed during World War II).

At the same time in New Castle-upon-Tyne in England, the first repair of a vascular injury performed in 1759 was documented (Figure 3). Hallowell, acting on a suggestion from Lambert, utilized the technique, known as the farrier's (veterinarian's) stitch, to repair a laceration of the brachial artery during an attempted bleeding from a brachial vein. He placed a pin through the arterial walls and held the edges in apposition by applying a suture in a figure-of-eight fashion about the pin.

19th century in the western world

Rudolph Matas of New Orleans, Louisiana, in the USA is given credit by many for being the "Father of Vascular Surgery," as well as being recognized as the first international American surgeon. His report of endoaneurysmorrphy in 1888 was an obliterative procedure treating arteriovenous fistulas. As far as can be determined, this was probably the first use of "endo" in relationship to the vascular system with endovascular now being very commonplace in the 21st century. There was a very important exchange between Matas and Soubbotitch of Serbia that will be further described in detail.

Although there were a variety of case reports related to the management of both arterial and venous injuries during the 19th century in the western world, the highlight was the first end-to-end anastomosis of an artery that was performed in Chicago, Illinois, USA by John B. Murphy, also, known for the "Murphy button" and for the Murphy auditorium at the American College of Surgeons in Chicago. At Mercy Hospital in Chicago, he treated an individual who had been shot in the groin one month earlier by repairing both the artery and vein in an arterial fistula (Figure 4). Others such as Dörfler at the end of the 19th century emphasized the use of fine needles and fine thread in the repair of arteries and veins.

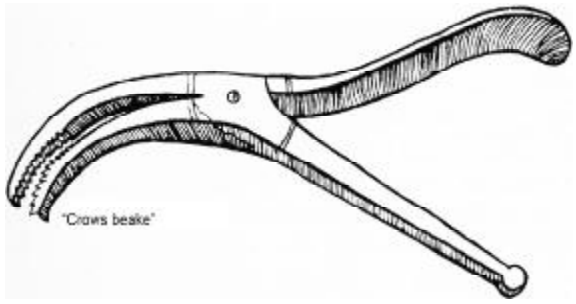

Figure 2. Artist's concept of the *bec de corbin*, developed by Paré in the middle 16th century. Vessels could be grasped prior to ligation. (From Rich NM, Spencer FC: Vascular Trauma. Philadelphia: WB Saunders, 1978.)

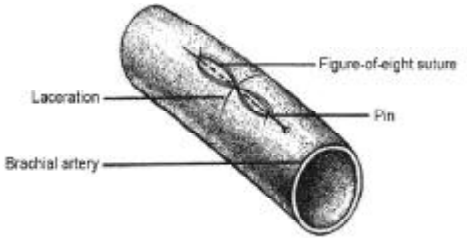

Figure 3. The first arterial repair performed by Hallowell, acting on suggestion of Lambert in 1759. The technique, known as the farrier's (veterinarian's) stitch, was followed in repairing the brachial artery by placing a pin through the arterial walls and holding the edges in the apposition with a suture in a figure-of-eight fashion about the pin. (Redrawn from the original description by Mr. Lambert: Med Obser Inq 1762;2:360) (From Rich NM, Spencer FC: Vascular Trauma. Philadelphia: WB Saunders, 1978.)

20th century

Voyislav Soubbotitch, serving in the Serbian Army in the Balkan Wars of 1911-1913, was "forty years ahead of his contemporaries," repairing both injured arteries and veins. These were performed in his university clinic in Belgrade, Serbia, and reported to an international surgical meeting in 1913. Matas and Soubbotitch met at that time and Matas wrote about the outstanding contributions of Soubbotitch. The surgical leaders of many European capitals visited Soubbotitch in his clinic prior to World War I to witness his unique and successful contributions in treating both injured arteries and veins.[17] Table 2 identifies acute arterial injuries

among British troops in World War I as documented by Makins in 1919. While this was not a true registry, it was one of the earliest efforts to document arterial injuries epidemiologically.

Table 2. Incidence of arterial injuries in combat

Artery	British World War I (Makins, 1919)		American World War II (DeBakey and Simeone, 1946)	
	Total	Percent	Total	Percent
Aorta	5	0.4	3	0.12
Carotid	128	10.7	10	0.40
External carotid			3	0.12
Renal			2	0.10
Vertebral	3	0.2		
Subclavian	45	3.7	21	0.85
Axillary	108	9.0	74	0.30
Brachial (total)	200	16.7	601	24.32
Above profunda			(97)	3.92
Below profunda			(209)	8.45
Radial-ulnar	59	4.9		
Radial			99	4.00
Ulnar			69	2.79
Radial and ulnar			28	1.13
Common iliac	1	0.1	13	0.52
External iliac	4	0.3	30	1.21
Internal iliac	1	0.1	1	0.04
Femoral (total)	366	30.5	517	20.92
Above profunda			(106)	4.28
Below profunda			(177)	7.16
profunda			(27)	1.09
Popliteal	144	12.0	502	20.31
Anterior tibial	26	2.2	129	5.22
Posterior tibial	97	8.1	265	10.72
Anterior and posterior tibial	7	0.6	91	3.68
Peroneal	4	0.3	7	0.28
Anterior tibial and peroneal	1	0.1	5	0.20
Both tibial and peroneal			1	0.04
Total	1202		2471	

Note: for Makins's data, there are three leg vessel injuries added in this list compared with the initial data; and for Debakey's data, the numbers in brackets are included in the total brachial and total femoral above. The reason why these numbers do not equal the two totals is that specific identification level could not be determined in all. (From DeBakey ME, Simeone FA: Ann Surg 1946;123: 534.)

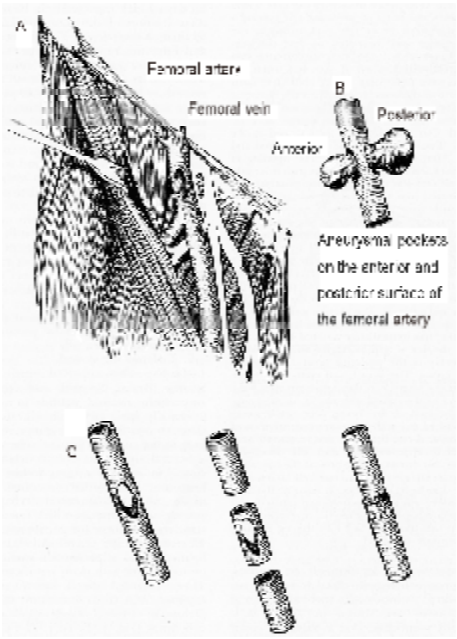

Figure 4. The first successful end-to-end arterial anastomosis in man in 1896 in Chicago by John B. Murphy is depicted above. A: The anatomic location to both the femoral artery and vein is demonstrated. B: The degree of arterial destruction is noted. C: A portion was resected and the repair of the moral artery after invagination is identified (Redrawn from Murphy JB: Med Record 1897;51:73.) (From Rich NM, Spencer FC: Vascular Trauma. Philadelphia: WB Saunders, 1978.)

Although the techniques were known and used both clinically and experimentally by the turn of the 20th century in the repair of both injured arteries and veins, ligation was preferred treatment in both World War I and World War II in the majority of vascular injuries in the extremities. Evacuation time averaged twelve hours in World War I, which added to the complexities. The adage "life over limb" was emphasized. Amputation of an injured extremity remained acceptable to preserve a life. As noted by Bertrand Burnheim in 1917 in France, infection was the rule rather than the exception in contaminated war wounds that received delayed medical and surgical attention. One should remember that there were no antibiotics and blood banking had not been developed. These two adjuvants came into being near the end of World War II. Table 2 lists the incidents of arterial injuries in the World War II in the European Theater documented by American surgeons supporting American military injured. All but 81 of the 2 471 acute arterial injuries were treated by ligation. During the Korean Conflict, for the American military medical activities, it was demonstrated by Hughes, Spencer and a few others that successful repair of both injured arteries and veins under less than ideal circumstances near

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the battlefield could be anticipated and achieved. Therefore, in the western world, we regard the early 1950s as the time when repair of injuries to both arteries and veins became more widely practiced. However, one contrast between the civilian and military management of vascular injuries has been the more aggressive repair of lower extremity venous injuries by the latter. There is an epidemiologic comparison with Makins' World War I arterial injury listing among British troops (Table 2).

The Vietnam Vascular Registry was established in 1996 at Walter Reed General Hospital to document and follow American casualties with vascular injuries in the Vietnam War. Table 3 identifies an interim report of 1 000 acute major arterial injuries in the Registry. There have been multiple additional reports and the long-term effort through the Registry continues. The total number of vascular injuries is now above 10 000 arteries and veins in approximately 7 500 casualties.

Table 3. Location of 1 000 acute major arterial injuries in the Vietnam Vascular Registry

Site	Artery	Number
Neck	Carotid	50
Chest	Innominate	3
	Subclavian	8
Upper extremity	Axillary	59
	Brachial	283
Abdomen and pelvis	Abdominal aorta	3
	Common iliac	9
	External iliac	17
Lower extremity	Common femoral	46
	Superficial femoral	305
	Popliteal	217
Total		1000

Note: data from Rich NM, Baugh JH, Hughes CW: J Trauma 1970; 10:359.

American military experience in Afghanistan started in 2001 and in Iraq in 2003. Our colleagues, through a variety of registry efforts, have been highly productive in their study as identified by selective references.[5,20-22] Reports from modern combat casualty care demonstrate a higher rate of vascular injury able to be treated at an earlier time after wounding.[23] In this context current efforts are focused at early restoration of flow following extremity vascular injury in attempts to improve functional limb salvage. In this context there has been a renewed interest in the effectiveness of temporary vascular shunts applied in select patterns of vascular injury.[24-25] Additionally, the implementation of catheter-based, endovascular technologies to treat certain injury patterns has now been shown to be feasible the austere conditions of war.[26] Obviously, this is evolving history that will have additional documentation in future years, including through the 3rd edition of *Vascular Trauma* by Drs. Todd E. Rasmussen and Nigel Tai of the United States and the United Kingdom, respectively.

Summary

This brief documentation of the management of injuries to both arteries and veins over the centuries, with an emphasis on the success in the western world in recent decades, is provided hoping to stimulate a response from others. We hope and trust that our Chinese colleagues will be enticed into providing a similar survey from their perspective as we all work together in a "shrinking world" to learn from each other.

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